

U.S. COAST GUARD

RADIONAVIGATION BULLETIN

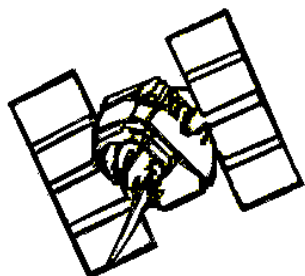
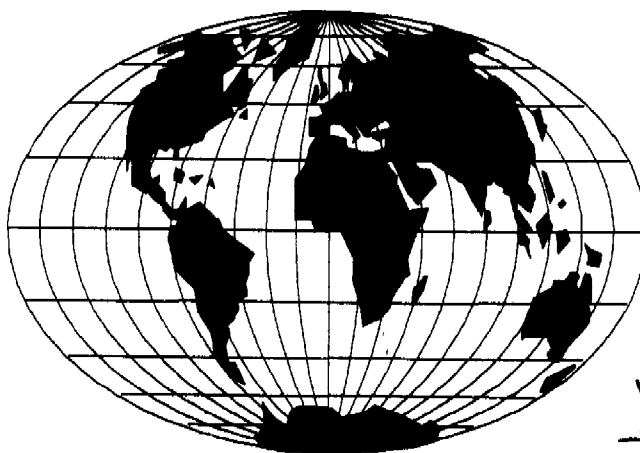
Fall/Winter Issue 1995, Number 30



OMEGA



LORAN-C



DGPS/GPS



RADIOBEACONS

INSIDE:

- IOC Declared for DGPS
- Electronic Navigation Projects at USCGA
- Omega of Omega

U.S. Coast Guard

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Contributors: Everyone is welcome to contribute articles. Articles for publication should be sent to : Commanding Officer, USCG NAVCEN, 7323 Telegraph Road, Alexandria, VA 22315-3998. Articles may be submitted in 10 or 12 characters per inch , or they may be submitted on an IBM-PC compatible, 3.5 or 5.25 inch floppy disk (returned on request). The *Radionavigation Bulletin* staff reserves the right to edit all material submitted. Copyrighted material will not be accepted without the author's and/or publisher's written release/permission.

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RADIONAVIGATION BULLETIN

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Coast Guard SDL No. 132

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INITIAL OPERATIONAL CAPABILITY PHASE DECLARED FOR U.S. COAST GUARD DGPS SERVICE

On January 30, 1996, the Honorable Federico F. Pena, Secretary of Transportation and Admiral Robert E. Kramek, Commandant of the U.S. Coast Guard, threw the ceremonial switch to declare the Initial Operational Capability (IOC) of the Coast Guard Differential GPS Service. During IOC, the DGPS Service is available for positioning and navigation. However, users are still cautioned to use all available navigational tools to ensure proper evaluation of positioning solutions. Also, during this IOC phase system validation tests are being conducted, procurement and installation of the next generation of radiobeacon transmitters are being pursued, the Control Station software is being upgraded, and the problems which were identified during the pre-operational phase are being resolved. These identified problems are ones that affected service availability of which the most critical are: Polestar transmitting antennas shorting due to ice and salt accumulation, ensuring accurate system monitoring to provide timely user notification, and numerous commercial power failures which take the sites off-air.

The successful development and implementation of the IOC DGPS Service was made possible through the concerted efforts of dedicated people from numerous commands and agencies. The following is a partial list of organizations who can be justifiably proud of their contributions (with apologies for any inadvertent omissions):

U.S. Coast Guard Offices

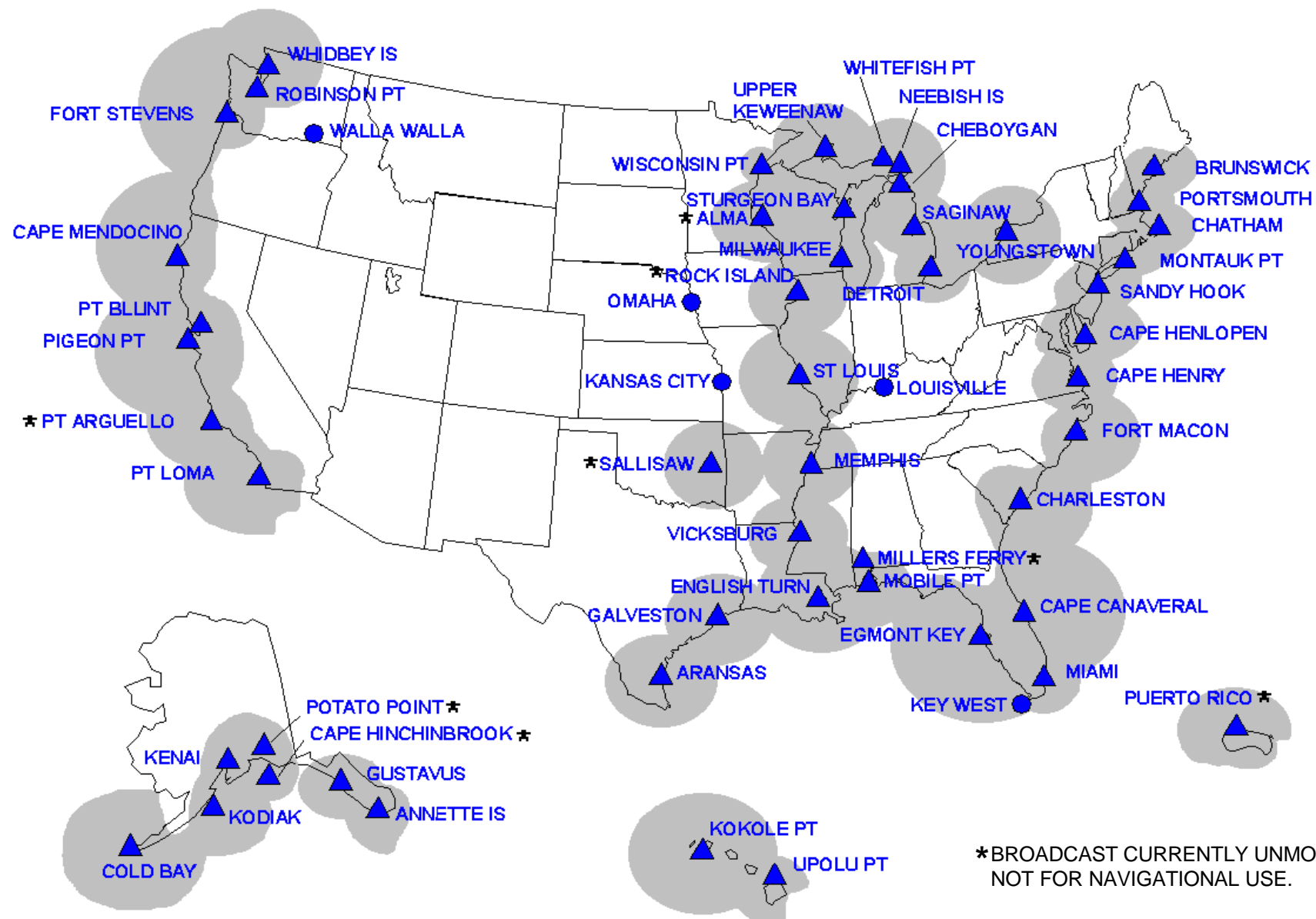
Academy
Aids to Navigation Team Ponce de Leon Inlet
Air Station Sitka
Bases Honolulu & Ketchikan
Civil Engineering Units Cleveland, Honolulu, Juneau, Miami, New York, Oakland & Providence
Commandant(G-A/E/N/T)
Districts (oan)
Electronic Maintenance Detachment Boston
Electronic Major Shops Telephone Cape Cod & Portsmouth Harbor
Electronic Support Units Alameda, Honolulu, Kodiak & Seattle
Electronics Engineering Center
Groups Astoria, Buffalo, Cape May, Detroit, Hampton Roads, Mayport, Miami, Milwaukee,
Mobile, Moriches, New Orleans, Portland ME & Sault Ste. Marie
Maintenance and Logistics Commands Atlantic & Pacific
Navigation Center
Research and Development Center
Reserve Training Center
Supply Center Baltimore
Support Centers Alameda & New Orleans
Telecommunication and Information Systems Command

Other Organizations

2nd Space Operations Squadron
Environmental Protection Agency
Federal Railroad Administration
Federal Communications Commission
Federal Highway Administration
Intelligent Transportation Systems Joint Program Office
National Geodetic Survey
National Oceanic and Atmospheric Administration
Pilots Association for the Bay & River Delaware
U.S. Air Force Space Command
U.S. Army Corps of Engineers



DGPS SITES 1 March 1996



*BROADCAST CURRENTLY UNMONITORED;
NOT FOR NAVIGATIONAL USE.

DGPS: IT'S AMAZING, IT'S FUN, IT'S HIGH TECH, BUT DON'T THROW AWAY THAT SEXTANT.

Now that Differential Global Positioning System (DGPS) is the talk of the town and as common as baseball, hot dogs, apple pie, and Chevrolet, (well maybe not baseball), it's time to take a closer look.

I am sure most of you are aware the Coast Guard is implementing DGPS throughout the continental U.S, Alaska, Hawaii, and Puerto Rico to provide a sub-10 meter navigation capability for vessel Harbor and Harbor Approach as well as for use in positioning and checking aids to navigation. We do this by providing real-time Global Positioning System (GPS) satellite range corrections over radiobeacon frequencies to users equipped with DGPS receivers. GPS alone provides accuracy of 100 meter or less, 95 percent of the time. Not bad, but it ain't differential.

It is amazing to think that by 'listening' to radiowaves generated from satellites 20 million meters in space, we are able to locate our position on earth (which is not so round, and not so flat). This real-time information has so many applications that soon, if it isn't already, it will become part of our everyday lives. DGPS is presently used by farmers and crop dusters to accurately fertilize and spray fields; by fish and wildlife personnel to map lakes and rivers for studying the growth rate of parasitic fish and algae; by law enforcement and emergency medical personnel to locate those in distress; by the Coast Guard for search and rescue (not much search anymore) and for positioning buoys; by industry worldwide to safely navigate planes and ships; by cities for intelligent vehicle highway systems such as locating buses real time and passing this information across cable television so riders can determine when to be at their bus stops (very helpful to elderly and handicapped persons); by surveyors for highly accurate positioning; by engineers for dredging operations; by businesses to track shipments sent by truck; and last but

certainly not least, to establish waypoints at the local golf course so you know exactly how far you are from the flag stick. These are, of course, only a few examples of GPS applications. Innovative ways to use the system are being discovered every day.

GPS is projected to become a 30 billion dollar per year industry in less than 10 years. It is definitely here to stay. Commercial vessel pilots in the Delaware River call and report using DGPS to safely navigate under the worst weather conditions imaginable. The system is extremely accurate and highly reliable. A Coast Guard Chief Petty Officer working aids to navigation reports that; "this DGPS is the cat's meow" (I think that means he likes it) as he used it to check buoy positions. His work load was shortened from a full day to less than two hours. We hear from many satisfied customers and it must be catching on because when a DGPS site goes off-air, many users call to tell us about it.

On November 1, 1995, the Coast Guard DGPS system began operation under a 'Preoperational phase.' This phase was used to operationally test and evaluate system performance. As a result, much was learned and many improvements to the DGPS service will be made over the next few years.

On January 30, 1996, DGPS entered an 'Initial Operational Capability' (IOC) phase in which the service is available for positioning and navigation. During IOC, enhancements to Control Station software and hardware will be accomplished, radiobeacon antennas will be upgraded to meet mission goals, transmitters will be replaced with new state-of-the-art equipment which operate with battery backup, and the DGPS service will undergo validation. All the while, coverage will be provided throughout North America with high availability. Upon completion of IOC, the DGPS service will be declared 'Full Operational Capability' (FOC) meeting all performance requirements with an availability of at least 99.7% (99.9%

for Vessel Traffic Service areas).

We've come a long way since Arab navigators used a "Kamal" (a knotted string held in the teeth and pulled taut against a site-board) to determine their latitude. For example, electronic chart displays that use DGPS pinpoint your location as if you were playing a video game, so even a child can steer a large ship through a narrow channel (do not try this at home). DGPS is great stuff! However, nothing is 100 percent reliable. Even the satellites we use to provide DGPS need repair from time to time. A rare occurrence, but it happens. So if terms like 'cross track error,' 'northing,' and 'easting,' have escaped you, then you may want to remain close to the pier. If you can't celestialize (I made it up) your way across the local fish pond then I suggest you leave nighttime sailing to the true navigators. They are the savvy salty sailors of the sea who have saved their sextants. I don't wish to sound pessimistic. After all, DGPS is "the cat's meow" and I am extremely optimistic that it will do all it is designed to do. As the DGPS Operations Officer working with this system for the past three years, I have confidence in this new technology and much appreciation for its capabilities. I just want to remind everyone that DGPS does NOT navigate, you do. DGPS is a navigational tool and like any other tool, you must know how to use it and what its limitations are.

The Coast Guard Navigation Center is staffed 24 hours/day to respond to DGPS emergencies. You, the user, are our most valuable source of information. Your feedback is instrumental in developing and enhancing DGPS. Please contact us if you have any comments or requests. You can write to us or call the East Coast DGPS Control Station at **703 313 5902**, or the West Coast Control Station at **707 765 7612**. A bulletin board service is also provided at **703 313 5910**.

We look forward to hearing from you. Have a safe boating day!

LCDR Gene Hall, NAVCEN

Electronic Navigation Projects at the United States Coast Guard Academy

The Electrical Engineering Section at the Coast Guard Academy has a research program based on student participation and dedicated to working on Coast Guard engineering problems. The research projects help the students bridge the gap between classroom learning and solving real-world engineering problems. Each project is assigned a technical advisor, a faculty project manager, and a cadet project manager.

Among our strongest supporters in this effort are the Radio Navigation Division at Headquarters (G-NRN) and the Navigation Center (NAVCEN) who provide us funds and sponsor our research. Over the years we have developed several niches in the CG electronics world. Because of the support of G-NRN and NAVCEN, our number one niche is electronic navigation research. This year is no exception -- one third of our research is in the area of electronic navigation. The projects include:

- Synchronization of LORAN-C to Universal Time Coordinated
- Applications of GPS Carrier Phase Processing
- GPS Receiver/Interference Research
- DGPS Signal Strength Data Collection Package
- Decorrelation of Ionospheric Delay and DGPS Accuracy
- GLONASS Research

Here is a brief description of each of the projects. For additional details please contact LCDR W.M. Randall at the Academy 860 444 8543.

Synchronization of LORAN-C to Universal Time Coordinated

This is a continuation of a project that has been going for several years. It is still being pursued to support the data collection system we currently have installed and are operating at Loran Station Seneca, NY. Our system is inexpensive and can be installed easily and accessed remotely. The goals for this year are to continue to

analyze the data, to modify the software code to improve the operator interface, and to develop an automatic reset in the event of a power failure or system casualty.

Applications of GPS Carrier Phase Processing.

We are investigating the use of carrier phase and precise ephemeris data from the National Geodetic Survey to do single receiver surveys at long distances from the reference receiver. One possible application of this technology comes from the National Data Buoy Center (NDBC). NDBC would like to accurately measure tidal wave height within a 4-6 cm tolerance in order to detect tsunamis in the Pacific Ocean. A kinematic GPS carrier phase solution is required for this type of vertical accuracy. Currently, successful kinematic solutions have been completed using expensive Ashtech single-frequency GPS receivers. This project will investigate the feasibility of producing solutions within the given parameters using a less expensive GPS receiver.

GPS Receiver/Interference Research

This basic GPS receiver study is using two different approaches: software modifications to an existing sliding replica correlator based receiver, and Digital Signal Processing (DSP) applied to digitized GPS RF signals. In the first case, with the Plessey GPS Builders Kit, we have complete control over the software and hardware. This capability allows us to write and test algorithms that will allow successful navigation using brief glimpses of satellites to calculate a "running" fix. Last year we modified GPS Builder software & hardware to give 2D fixes with 2 SV's and a precise clock and are now moving toward being able to successfully navigate in urban canyons and other areas of sporadic signal availability. In the second case, we have demonstrated the ability to obtain GPS fixes

with as little as 1 millisecond of data and have found dramatic improvement in fix availability in downtown Hartford relative to a conventional receiver. We are now focused on interference issues. Since much of the processing is done in the frequency domain, interference measurements and filtering can be accomplished very easily. In addition to interference issues, the study is intended to develop GPS expertise within the Academy faculty to continue teaching electronic navigation to cadets, officers, CPOs, civilians, etc.

DGPS Signal Strength Data Collection Package

It is easy to understand why the signal strength of the DGPS beacons is useful information, but measuring that signal strength in the field has been a tedious process of manually recording the position and the signal strength one frequency at a time. Our plan is to develop a suite of equipment, controlled by a laptop computer, and including a DGPS receiver and a portable analog spectrum analyzer. The computer will record the specific beacon frequency, the signal strength, and the position to a file and then switch frequencies to allow us to collect data as we transit from one beacon coverage area to another.

Decorrelation of Ionospheric Delay and DGPS Accuracy

The Coast Guard DGPS system has the ability to transmit RTCM SC-104 Type 15 messages containing measured ionospheric delay. This project is attempting to determine if a dual-frequency user receiver can obtain better accuracy by using the difference between transmitted and locally-measured ionospheric delays as additional pseudorange corrections. Preliminary results based only on ionospheric delays calculated from dual-frequency pseudoranges have indicated no improvement. The

INTERNATIONAL NAVIGATION ASSOCIATION (INA)

The International Navigation Association (INA) will hold its annual meeting August 6-9, 1996 in Helsinki, Finland. USA contact:
INA, INC., PO Box 2324,
Arlington VA 22202-0324
or FAX 604 274-8156.

effort is now focusing on more complex delay estimation algorithms using carrier phase in addition to pseudorange data.

GLONASS Research

GLONASS is the Russian equivalent of our GPS system. Selective availability is not implemented in GLONASS and both civil and military users have access to dual frequency Pcodes (@ 5.11 MBPS). Therefore, if the GLONASS clock and ephemeris data were as good as those of GPS, the accuracy would be nearly as good as dual frequency military GPS accuracy, but based on daily fix plots this is not necessarily true. Using funds provided by G-NRN, we just purchased a GLONASS receiver identical to what USNO recently pro-cured. With this receiver, beginning in January, we intend to cooperate with USNO in looking at time stability and offsets between GLONASS and GPS time scales. Having multiple sites with redundant Cesium time standards should help in isolating clock from ephemeris errors. We are also considering studying integrated GLONASS/GPS navigation and tracking receivers.

CAPT B. B. Peterson, USCGA
LCDR W. M. Randall, USCGA

***LORAN-C Plotter Cards
are available from NIS:
703 313 5900.***

NEW TIMING AND CONTROL EQUIPMENT FOR OMEGA

The final station to receive the new Omega Timing and Control (T&C) equipment, Omega Station Liberia, will undergo this upgrade in the spring of 1996. The other seven Omega stations have already had their new equipment installed and are operating successfully.

The question might arise, why are we putting in new equipment now when there is talk about the Omega system being terminated in less than 2 years? Until the issue of the 1994 Federal Radionavigation Plan (FRP) in the spring of 1995, the Omega system was supposed to continue in operation at least until the year 2005 and possibly longer. As early as the late 1980s it was realized that the existing timing and control equipment for the Omega system could not be supported up through the proposed end date of 2005. This equipment had been designed in the 1960s and certain critical components were obsolete and could no longer be obtained for replacement purposes. Therefore, an extensive redesign program was undertaken at the Coast Guard Navigation Center (NAVCEN) to develop new and improved equipment.

The new T&C equipment employs up-to-date electronic and computer techniques including microprocessors, digital signal processors, software control, data bus communications, video screen

menus, and keypad selection. These techniques provide additional features, and improve operation and support logistics. The design was sent to a manufacturer, and all of the new equipment was purchased and much of it installed before the latest FRP changed the Omega termination date to 1997. Since the equipment had already been built and delivered to NAVCEN, and the benefits of employing the new equipment were still valid, the installation proceeded as planned.

The benefit of the new, improved, equipment will mean at least 18 months of high quality operation at Liberia lasting right up to the last minute. And, in the event the Omega system continues beyond September 1997, all of the new T&C equipment will already be in place for quality operation.

Another benefit to completing the installations at all the stations is the savings of space and documentation. Once the last set of new equipment is installed at Liberia, NAVCEN will no longer need to support two sets of equipment (old and new) as it has for the past several years. This will free up space both at NAVCEN and the Coast Guard Supply Center in Baltimore, Maryland, by eliminating the need for all stock, spares, and documentation relating to the old system.

R.C. Hoyler, NAVCEN

INTERNATIONAL OMEGA TECHNICAL COMMISSION

The next International Omega Technical Commission (IOTC) meeting will be held April 15-19, 1996, in Melbourne, Australia. The IOTC consists of representatives from the governmental operating organizations of each of the seven Partner Nations (U.S., Norway, Liberia, France, Argentina, Australia and Japan). They meet in alternate years to discuss overall policy and operational issues. The main area of discussion at the upcoming meeting is expected to be the termination of Omega presently planned for September 1997. U.S. attendees will include CAPT Robert J. Wenzel, Commanding Officer of the USCG Navigation Center, Mr. Stewart Shoulta, Program Manager of Omega Termination at the USCG Headquarters Radionavigation Division, and Mr. Robert Hoyler, Engineering Division Chief at the USCG Navigation Center.

OMEGA OF OMEGA

Omega is the last letter in the Greek alphabet, and is often used to mean "the end." It is also the name of the worldwide ground-based VLF (very low frequency) radionavigation system that has been operated by the U.S. and six Partner Nations since the mid-1970s.

The latest (1994) U.S. Department of Defense (DOD) & Department of Transportation (DOT) Federal Radionavigation Plan (FRP) states that the U.S. expects to terminate its participation in the Omega system on September 30, 1997. Activities are underway at the Coast Guard Navigation Center to work towards this scheduled termination date. A Natural Working Group has recently been formed with the charter to "Develop an orderly process for ending the U.S. Coast Guard's involvement in, and the termination of, the world-wide Omega Navigation Service by scheduled date in 1997."

This effort involves planning diverse activities ranging from informing users (of which there are still many), terminating the International Agreements with the Partner Nations, making all the spare parts come out even on the last day, to ultimately disposing of all the electronic equipment and U.S.-owned facilities. Turning off a system such as Omega is much more complex than just saying "last one out the door shut off the lights" and leaving everything there.

Each Omega station includes a 1200-1400 foot antenna tower or a valley span antenna consisting of heavy wires strung between mountains. These things can't just be left standing there without aircraft warning lights on the towers or ongoing maintenance to prevent possible catastrophic collapse. They either have to be dismantled or transferred over to some agency which will utilize them for ongoing purposes and provide appropriate upkeep. Similarly, the electronic

equipment owned by the U.S. Coast Guard, in general, as per the International Agreements, must be properly disposed of after termination of the system.

With few exceptions, the specialized equipment used to generate and transmit the unique Omega signals would be of no use to anyone, other than to take apart for electronics parts, nuts and bolts, or to use as the proverbial boat anchor. The few exceptions, would be the multi-purpose computers and test equipment which could be salvaged for other uses.

There have been many concerns voiced about shutting the system off expressed in letters sent to various U.S. government agencies and discussions at navigation meetings. Users are understandably concerned about "putting all their navigation eggs into one basket" (referring to the GPS system). Navigators everywhere are concerned about losing an operational system making it harder to follow the recognized concept that "the prudent navigator never relies on only one system." Others have voiced the opinion that Omega has long since been certified for oceanic navigation, and recognizing the difficulty in getting any new system certified, it would make sense to keep the Omega system as a backup. The navigation industry is beginning to discuss and recognize that the GPS system is not as close to 100% reliable in either time or location as desired and previously considered.

The Federal Aviation Administration (FAA) has been examining airlines who have not yet switched over to GPS and continue to use Omega. At least one major U.S. airline has several hundred aircraft operating with Omega navigation equipment. In addition to the cost of switching to a new navigation system (GPS), it takes a considerable amount of time to equip an aircraft fleet with a new navigation system. New equipment must be purchased, and

then each aircraft must be taken out of service to install the equipment and obtain certification. Out-of-service aircraft are a major investment not producing any financial return for the airline.

Worldwide weather services launch between 200,000 and 400,000 weather balloons each year to collect data on upper atmosphere wind speed and direction. These throwaway balloons use Omega for tracking because of the low cost of the Omega receivers (actually transponders). Recent analyses indicate that the total system cost using the presently more expensive GPS receivers would exceed the cost of operating the entire Omega transmitting system. (The weather balloon companies claim they can use existing Navy VLF communications stations to provide tracking in lieu of Omega, despite the fact that the Navy has repeatedly stated that these stations cannot guarantee availability due to their own operational reasons.) Former Omega transmitting stations can be simplified to be useful for weather balloon tracking with a lower operating cost than the cost for full Omega service.

What will happen in the future remains to be seen. The next FRP is due out sometime in 1996. Meanwhile, the Omega termination wrecking ball is starting to swing, picking up speed as it approaches the proposed shutoff date of September 30, 1997. The faster it goes as the date approaches, the harder it will be to stop it.

R.C. Hoyler, NAVCEN

U.S.C.G. NAVIGATION INFORMATION SERVICE

In my last article, I mentioned that the Navigation Information Service (NIS) would have an Internet connection in the near future. Well, as of July 1, 1995, NIS began providing information services via Internet.

NIS WORLD WIDE WEB.

<http://www.navcen.uscg.mil>

or

<ftp://ftp.navcen.uscg.mil>

You will find that most of the information provided on our Fax on Demand (FOD) and our Bulletin Board Service is also located on our Web site. If you have any questions about our services you can send us an email via the Internet to: **webmaster@glacier.navcen.uscg.mil**

NIS Fax on Demand (FOD)

To contact the FOD, call: **703 313 5931/32**

NIS BULLETIN BOARD SYSTEM (BBS)

To contact the BBS, call: **703 313 5910**

Users who need further information or assistance may call the
NIS watchstander at: **703 313 5900**

QMCM J. Mauro, NIS

Civil Global Positioning System Service Interface Committee (CGSIC)

The Civil GPS Service Interface Committee (CGSIC) was established to exchange technical information and to identify any issues that may need resolution by DOT's POS/NAV Executive Council. Attendance is open to anyone with a need to exchange information or provide input regarding civil GPS requirements. Currently, the membership represents a variety of countries (53) and disciplines.

The 26th Meeting of the CGSIC was held in September in Palm Springs California. The Meeting Summary is available on the NIS Bulletin Board. The 27th Meeting was held March 19-21, 1996, at the DoubleTree Hotel in Tysons Corner, Virginia. Agenda topics included: GPS Status- AF Space Command, Rand Report, Block IIR and Block IIF Status, Interference and frequency spectrum management, and International Updates from country representatives. You can obtain additional information on the CGSIC and the CGSIC meetings by contacting Ms. Rebecca Casswell at the Coast Guard Navigation Center at **703 313 5930** or **FAX 703 313 5805**.

CIVIL GPS SERVICE INTERFACE COMMITTEE- INTERNATIONAL INFORMATION SUBCOMMITTEE MEETING

The International Information Subcommittee (IISC) of the CGSIC held a meeting in Amsterdam, Netherlands on 5-6 December 1995. Approximately 80 attendees represented government, industry and universities from Europe, Asia, and the United States. The agenda included presentations on: the European Radionavigation Plan, the development of EGNOS, how each country is using GPS, the U.S. Civil GPS Service, and GPS user requirements for land, air, sea, and timing. The summary of the Amsterdam meeting is available on the Navigation Information Service web site.

Federal Railroad Administration Looks At DGPS as Aid to Positive Train Control

The Federal Railroad Administration (FRA) is looking to Differential GPS as an aid to Positive Train Control. Last June the FRA submitted to Congress' Committee on Appropriations a report titled "Use of Differential GPS to Aid Positive Train Control." The following is the Executive Summary which accompanied the report.

"The report of the Senate Appropriations Committee on the Department of Transportation and Related Agencies Appropriations Bill, 1995, directed the Federal Railroad Administration (FRA) to submit a report regarding the benefits, costs, desirability, feasibility and implications of using current and planned 'differential GPS' as a means of promoting the accuracy and utility of positive train control systems. Positive train control systems are technologies having the capability of preventing collisions between trains, avoiding overspeed derailments, and providing other safety and economic benefits.

"The Global Positioning System (GPS) data available to civilian users is not sufficiently accurate to meet the safety-related needs of transportation users. The United States Coast Guard is deploying a differential correction service for GPS to enable precision navigation in harbors and inland waterways. Railroads are exploring use of this differential GPS service as a location determination system in emerging communication-based train control systems.

"FRA strongly supports development and implementation of communication-based positive train control systems. Such systems have the potential to significantly enhance railroad safety and to provide many additional benefits, including full exploitation of potential line capacity by freight and passenger railroads. Such systems can also lower the cost of train control for new high-speed rail service.

"The two primary train location systems that have been actively considered for use in communication-

based train control systems are based on differential GPS and transponders. North American railroads are exploring the use of both of these location determination systems. At the present time, differential GPS appears to have the advantage of lower initial cost (e.g., all necessary hardware can be placed on the locomotive) and less maintenance (e.g., transponders can be damaged by vandalism or routine track work). The Burlington Northern Railroad and the Union Pacific Railroad have joined together to develop a Positive Train Separation (PTS) Pilot Project on their lines in the States of Washington and Oregon that will employ differential GPS as the primary location determination system.

"Differential GPS will soon be available to marine users all along the U.S. coast line and throughout our principal inland waters. With an incremental expenditure of less than \$25 million, sufficient additional transmitters could be placed to provide total coverage of the 48 contiguous States. This highly accurate location determination system could then be used by both rail and highway users, among others. Public deployment of differential GPS will be necessary if this system is to be used by railroads. Private differential services do not offer high reliability, consistent protocols and full land area coverage - attributes that are essential to interstate rail movements employing interoperable train control systems.

"Implementation of communication-based positive train control can prevent accidents and casualties valued at approximately \$35 million per year. However, the initial costs of positive train control systems for U.S. railroads may approach over \$800 million. In addition to equipping trains with location systems, positive train control will require the use of on-board computers, extensive data bases, data radio systems along the principal rail lines, and development of complex on-board and 'central office' software. These are costs that private

railroads will shoulder to the extent they are convinced that adequate business benefits will result. The Union Pacific/Burlington Northern PTS Pilot Project is persuasive evidence that emerging business needs and maturing technology will converge, leading to the requisite private investments.

"Non-safety benefits of positive train control may include better quality service and more efficient equipment utilization through closer tracking of car movements, reduced fuel consumption through pacing of trains, and more effective use of existing infrastructure that effectively increases the capacity of the railroad. Public passenger service providers that operate over freight railroads would also benefit from the capacity and safety benefits of this kind of technology. Over time, intermodal application of communication-based technology could link highway-based intelligent transportation systems with positive train control systems to yield synergies such as improved safety at highway-rail crossings.

"In summary, full deployment of U.S. Coast Guard differential GPS can significantly aid development of positive train control systems by providing an affordable and competent location determination system that is available to surface and marine transportation throughout the contiguous United States."

Burlington Northern Railroad has merged with Santa Fe Railroad. Burlington Northern-Santa Fe Railroad and Union Pacific Railroad hope to have their Positive Train Separation System installed and operating by August/September this year. A planned DGPS site on the Columbia River at the McNary Dam in Walla Walla, Washington, will be used along with the present Washington DGPS sites at Fort Stevens, Whidbey Island and Robinson Point. The project involves the cooperation of the FRA, the Coast Guard and the Army Corp of Engineers.